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Oil spill dispersants

Risk assessment for Swedish waters

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Sammanfattning/Summary

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Foreword

The Environmental Advisory Service for Oil and Chemical Spills at IVL, Swedish Environmental Institute, has, upon request of the Swedish Environmental Protection Agency, researched international uses of dispersants at oil spills and conducted a risk assessment of the use of dispersants in Swedish coastal areas.

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1. Introduction

Over the past few years, the use of dispersants has become an increasingly common method to combat oil spills in seas. The reason for this is in part because new dispersants have been developed, which are significantly less toxic than their precedents, and in part because current mechanical methods have definite limitations. This has led to a change in attitudes both nationally and internationally. Several countries have expressed positive attitudes towards dispersants and have therefore softened their views on the use of such products.

This report aims to give an overview of the international usage of dispersants and their biological effects. IVL has conducted a risk assessment of whether dispersants can be used in Swedish coastal areas. Included in the risk assessment is an analysis of the pros and cons to using dispersants against oil spills in seas, together with recommendations on the use of dispersants in Swedish waters. IVL also presents identified weaknesses in current knowledge and provides suggestions on how these can be addressed.

2. Summary

IVL has compiled a list of the international usage of dispersants and presents the technical limitations with the use of such agents as well as the biological effects of these chemical products. The technical limitations in today's dispersants are sensitivity for low salinity, for low water temperatures, as well as for the oil's consistency – dispersants are not as effective on weathered or thick oil as with fresh oil. Research on the toxicity of oil mixed with dispersants has shown a high toxicity value amongst aquatic organisms even when the dispersant itself was not the least bit toxic. The research even showed that the result regarding dispersant's effectiveness varied depending on who carried out the test, which suggests that judgements on the effectiveness of dispersants are not always representative.

IVL has conducted an analysis of the pros and cons to using dispersants against oil spills in waters and has applied this with a risk assessment of chemical methods to combat oil spills in the Kattegat and Skagerrak and the Baltic Sea. The relatively high salt content in the Kattegat and Skagerrak make it possible to use dispersants as a combat method, but the sea's amount of mixing energy is kept low by a strong halocline which limits vertical mixing. The Baltic Sea's hydrographical properties such as a low amount of mixing energy and low salinity do not make the Baltic Sea an ideal environment for chemical dispersion of oil. Chemical methods in both the Baltic Sea and the Kattegat and Skagerrak are limited in the wintertime by low water temperatures where dispersants' effectiveness are low. Should an oil spill happen far out in the sea, it

may take a long time before it is noticed, at which point the oil will have undergone major weathering processes thereby making the use of dispersants ineffective. Many breeding areas in both seas can be damaged by chemical recovery methods. Given the various factors working against effective dispersion, namely water temperature, salinity and amount of mixing energy, IVL does not recommend the of use oil spill dispersants as the critical factors are not optimal in either the Kattegat and Skagerrak or the Baltic Sea.

Gaps in the knowledge identified over the course of the study are how dispersants spread and how dispersants and dispersed oil bioaccumulate. Before dispersants can be recommendable at all, more studies need to be conducted on the long-term effects of dispersants on aquatic organisms.

3. Background on the chemical composition and function of dispersants

When oil is introduced into a water environment, the spill will spread horizontally on the water surface. Spreading varies with surface tension at the border between the oil and water. The higher the oil surface tension (and therefore the surface tension between the oil and water), the less the oil spreads. With the help of dispersants, one can lower the surface tension of the oil so that it spreads more easily.

Dispersants are comprised of three main components: surfactants, solvents and additives. Solvents must be used because the surfactants are often viscous or solid, and are either hydrocarbon-based or water-based. Surfactants are the active component that lower the surface tension in the area between the oil and the water and speeds up the dispersion of the oil. Surfactant molecules are composed of a water soluble (hydrophilic) part and a hydrocarbon soluble (lipophilic) part and has the ability to orientate itself in the border area with the hydrocarbon soluble group in the oil and the water soluble group in the water (see Figure 1). Another important component of dispersants is the additive, which stabilises and prevents the oil particles from breaking away from the border area between the oil and the water.

The dispersion process also requires a certain amount of mixing energy and some dispersants require a specific wave movement or other form of energy (e.g., driving a boat over the treated area) so that the bipolar molecules can properly orientate themselves at the phase surface under the oil. There has even been a development of products that can work well without the provision of mechanical energy.

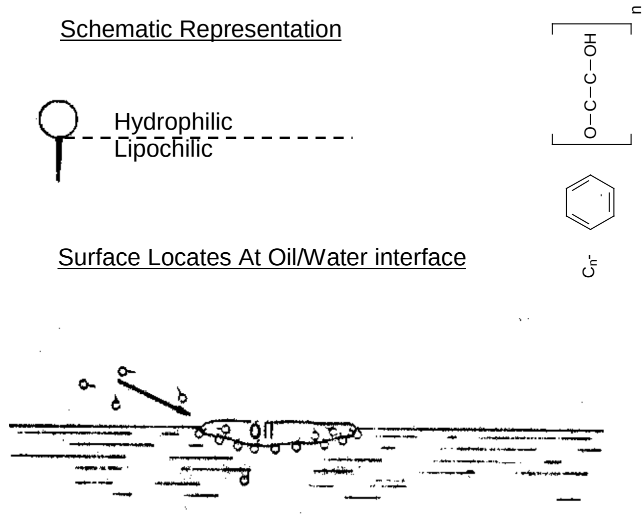

Figure 1. The chemical composition and function of dispersants.

4. Current dispersants

4.1 History

Since the 1950's and 1960's, when oil transportation exploded and the number of accidents increased, dispersants have developed over what one usually divides into three generations. The first generation of dispersants that came out on the market were hydrocarbon-based and were made of aromatic hydrocarbons, which gave rise to toxic effects. The second generation of dispersants that developed, the so-called 'conventional dispersants', contained no aromatic hydrocarbons and are used today in seas where they are applied directly from vessels without dilution. Conventional dispersants are starting to be replaced by the third generation of dispersants, the so-called 'concentrated dispersants' because these are easier to handle during clean-up operations. Concentrated dispersants are diluted with water before application, such that the volume problem on vessels and aircrafts decreases. Third generation dispersants are usually divided into two types based on their solvent agent – water-based or hydrocarbon-based.

Water-based concentrated dispersants have a comparatively low toxicity, but require a longer time to disperse oil than ready-mixed products. Due to this time lag, there is a risk of using too much water-based dispersant before the process is complete. The hydrocarbon-based products have a higher toxicity than water-based products but require a lower dose with application. The manufacturers therefore claim that the toxicity levels of both types of products are low. A summary of dispersants used today is provided below (Table 1).

Table 1. The table summarises the dispersants used today, application methods and dosages. (BONN Agreement, 2001)

Standard name	Generation	Type	Application method	Solvent	Dosage (dispersant/oil)
Conventional dispersants	Second	1	Not diluted on ships	No aromatic hydrocarbons	30-100%
Concentrated dispersants	Third	2	Diluted on ships	Water-based (e.g., glycol ether)	5-15% (concentrated products)
		3	Not diluted on ships or airplanes	Hydrocarbon-based	

4.2 Technical limitations

The water-based dispersants' solvent is made up of alcohol, glycols and glycol ethers (mostly ethanol, isopropane, ethylene glycol and propylene glycol) to increase its ability to mix with oil and lower the freezing point. Surfactants make up over 20% of these dispersants. The dispersant is applied from ships and diluted before application. Water-based dispersants require a relatively long time to complete dispersion. It has been argued that exceeding the dosage of these substances is common because people's expectations for oil dispersion are too high. The most important limitation is their sensitivity for extreme temperatures. At high temperatures, there are security risks as certain solvents used in products are fire-hazardous. The most critical temperature area, though, is under 0°C, because the risk for refreezing in the spreading device is high. In addition, the dispersant's viscosity increases, which can lead to dosage problems (Lehtinen, 1981).

The development of concentrated hydrocarbon-based dispersants, also known as self-mixing dispersants, has made the dispersion of oil on the sea surface much faster and easier. Self-mixing dispersants are spread from aircrafts, which means a doubling of the capacity. The limitation in this method is access to chemicals, because a small, light aircraft can only take a load of 400-500L. If the oil spill is very large a plane with a larger capacity and range, which can take loads up to approximately 11 tonnes, is needed. Successful air application depends largely on the weather (the wind).

Another weakness with today's dispersants is their sensitivity to low salinity. As Figure 2 shows, the salinity of the water is directly proportional to the effectiveness of the agent – with decreased salinity one sees decreased effectiveness (Lehtinen, 1981). The chemical explanation for saltier and ion-rich water showing better dispersion of oil is the electronic properties of the surfactants' hydrophilic component and the attraction between water molecules and surfactants (Solyom, pers. comm. 2001).

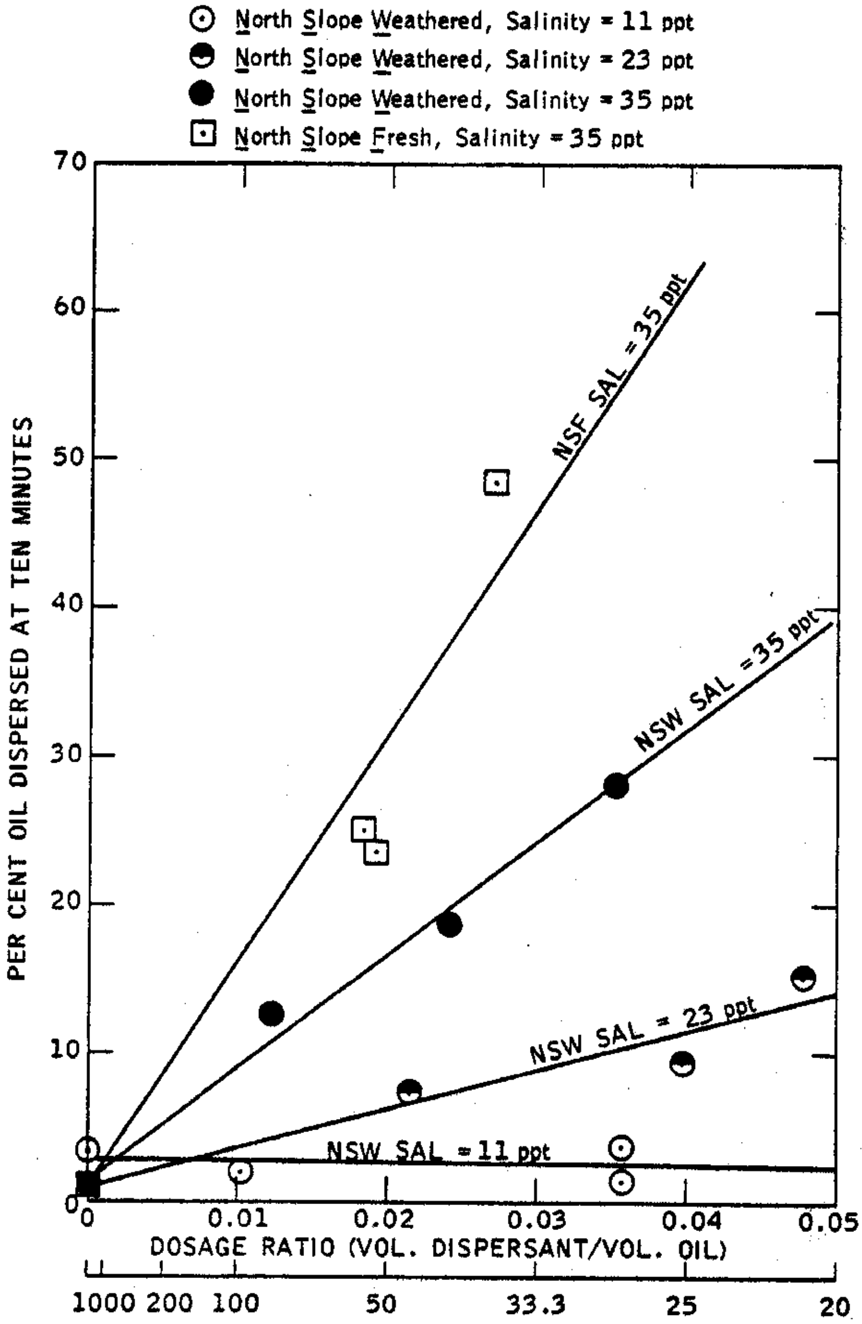

Figure 2. Water's salinity is directly proportional to how much a certain oil can disperse. The figure illustrates the oil North Slope at various salinities. (Lehtinen, 1981).

Other factors that affect dispersants' effectiveness are water temperature and the oil's physical properties. Figure 3 shows how effectiveness of the dispersant increases with increased water temperature. The oil's properties also strongly influence the dispersion process. The more weathered or thick the oil is, the less effective the dispersants will be (Figure 4) (Lehtinen, 1981).

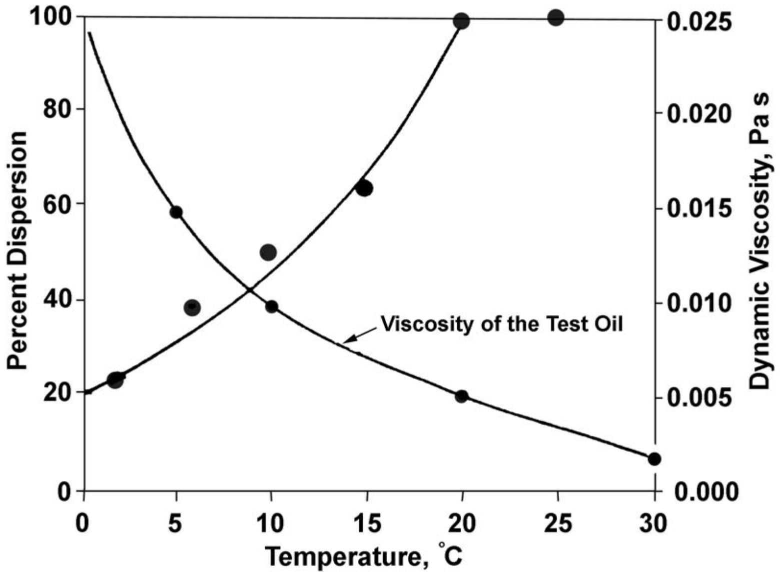

Figure 3. The dispersant's effectiveness increases with increasing temperatures. (Lehtinen, 1981).

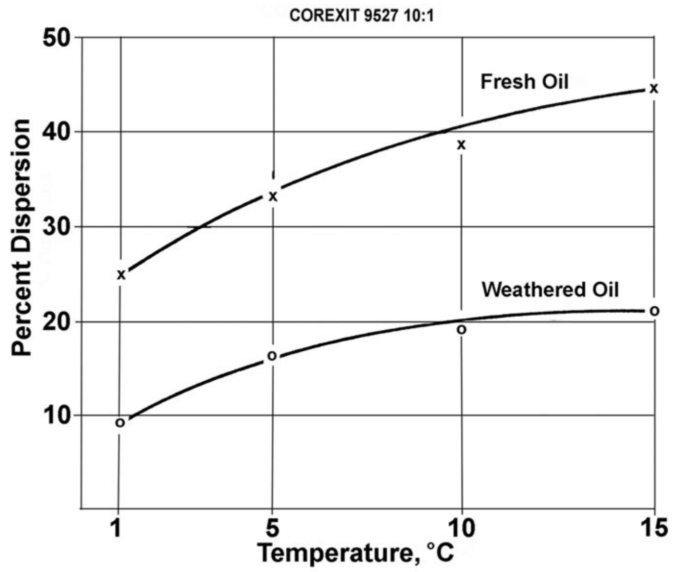

Figure 4. The oil's properties affect dispersion. Dispersants are less effective on weathered or thick oil than with fresh oil. (Lehtinen, 1981).

5. Use of dispersants in Sweden

Sweden currently has restrictions on the use of dispersants for combating or cleaning up an oil spill (SNF 1986:6). According to these regulations, Sweden may use dispersants in open waters over one nautical mile from the shoreline at low tide if this method is deemed necessary, effective and environmentally preferable to other methods. As per §3: ”the Swedish Environmental Protection Agency shall be consulted before any oil combating action is taken if it is deemed that more than 10 m^3 of concentrated dispersants will be used for a given oil spill." "Within a line one nautical mile beyond the baseline of Swedish waters and in marine biologically sensitive areas outside the baseline, dispersion shall not be approved without permission from the Swedish Environmental Protection Agency " (Naturvårdsverket, 2001:§4). Sweden has currently got rid of all its supplies of dispersants and has stopped using these products (BONN Agreement, 2001).

6. International uses of dispersants

The international usage of dispersants against oil spill, presented in this section is divided into the Baltic Sea region, other Europe, Canada and USA.

6.1 Baltic Sea region

The Baltic Sea's coastal states are contracting parties in the Helsinki Commission (HELCOM; Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden and the Russian Federation). HELCOM's recommendations for combating oil spills in the Baltic Sea are above-all mechanical actions and to avoid the use of dispersants for as long as possible (HELCOM, 2001).

6.1.1 Denmark

Denmark almost exclusively uses mechanical combat methods for oil spills. In special cases, chemical dispersants are used, provided such action is approved by the Danish EPA. In exceptional situations, oil platforms, ports and refineries have the right to use up to 50 litres of dispersant for a given accident (Danska EPA, 2001).

6.1.2 Estonia, Latvia and Lithuania

The right exists in Estonia to use dispersants against oil spills. General recommendations have been developed for this purpose. However, Estonia predominantly uses mechanical methods to combat oil spills and no permit has been issued to use dispersants since 1992. The use of dispersants in Latvia has not been prevented. The right exists to use dispersants in the open sea, although it is forbidden to use non-mechanical methods in port areas. Handling of dispersants and the removed oil shall follow general recommendations established by the Marine Environment Board. In Lithuania, the use of dispersants is allowed if permission is granted by the Klaipeda Regional Department of Ministry of Environment, but no license has been granted since the country has gained independence (HELCOM, 2001).

6.1.3 Finland

Finland exclusively uses mechanical methods to combat oil spills. Regulations and criteria for the use of dispersants are missing. In a report on the implementation of HELCOM's recommendations, Finland brought forth that ice-filled water and difficult weather conditions make it difficult to use mechanical methods. The report emphasises the need for control with the help of chemicals and educated people in the area. (HELCOM, 2001).

6.1.4 Norway

Norway predominantly uses mechanical methods to combat oil spills. However, dispersants may be used as a stand-alone method or in combination with mechanical methods. The rules regarding the use of dispersants are currently under review (BONN Agreement, 2001). Table 2 summarises dispersants that may be used in Norway.

6.1.5 Poland and Russia

Poland has similar policies regarding dispersants as other Baltic States – to predominantly use mechanical methods to combat oil spills and that dispersants may only be used in special cases. Permits are granted by the Director of Maritime Board. Russia, on the other hand, takes a more positive position towards the use of dispersants than other Baltic states and has used the products OM-6, OM-84 and Corexit 9527 since 1984. Russia plans to continue using chemicals to combating oil spills in seas (HELCOM, 2001).

6.2 Other Europe

6.2.1 Belgium

Belgium has no specific rules for the approval of dispersants, although general recommendations on the control of oil have been established by the Ministry of Health and Environment. The deciding body for the use of dispersants in Belgian waters is the government. If it is decided to use dispersants as an action against an oil spill, every specific event shall be evaluated based on the oil's behaviour and potential biological effects over time, with or without the use of dispersants (Bonn Agreement, 2001).

6.2.2 France

France uses dispersants as a method to combat oil spills when it is deemed appropriate, e.g., in situations with large quantities of oil. Geographical borders have been drawn in French waters and beyond these borders it is believed that using dispersants against oil does not bring about any major effects on the marine environment. These borders have been defined in relation to scenarios of oil spills of up 10, 100 and 1000 tonnes and the dispersant's environmental effects in the area. Within these borders, certain safety precautions must be followed with the use of dispersants (Bonn Agreement, 2001). Table 2 summarises the products that may be used in France.

6.2.3 England

In England, the total number of approved dispersants is high in comparison with other countries and large amounts of chemical products are used against oil spills. The application of dispersants is largely done by aircraft. Dispersants are used as a combat method when oil spills threaten England's natural resources, such as the rich bird and marine life along the coast, as well as when weather-permitting and the oil is deemed dispersible. Operations with chemical products on oil spills are only launched after the decision is made by experts.

Approval by the government (Fisheries Department) is required in England for the use of dispersants in waters less than 20m deep. Only dispersants that have undergone relevant tests may be used (as per the Food and Environmental Protection Act, 1995 and the Deposit in the Sea Order, 1985) (Bonn Agreement, 2001). Table 2 summarises the products approved in England.

6.2.4 Germany

Germany has developed new general recommendations for dispersants whereby their use is highly limited in coastal waters. As a rule, as like England, such products may not be used in waters less than 20m deep. Restrictions for the application of dispersants in open waters are less restrictive, but mechanical methods are given higher priority at oil spills (Bonn Agreement, 2001).

6.3 Canada

Canada primarily uses mechanical methods to combat oil spills. Dispersants are only used when weather prevents the use of other methods. Dispersants are applied through spraying from vessels or aircrafts. Environment Canada is responsible for the approval and administration of products. Table 2 summarises the products that have been granted approval by Environment Canada. (Environment Canada, 2001).

6.4 USA

Dispersants as a method to control oil spills have not been used in most areas of USA, in part because of the difficulties of applying dispersants at oil spills, and in part because of lack of agreement amongst researchers regarding the effectiveness and toxicity of the products. The agency responsible for approving dispersants is the United States Environmental Protection Agency (USEPA). (USEPA, 2001). Table 2 summarises the dispersants approved by the USEPA.

Table 2. Overview over permitted dispersants in various countries.

Dispersant	Permitted in
Corexit 9500	France, Canada, Norway, UK, USA
Corexit 9527	Canada, Norway, USA, UK
Corexit 9550	Canada
Corexit CRX-8	Canada
Dasic Slickgone LTSW	Norway, UK
Dasic Slickgone NS	France, Norway, UK
Dispersit SPC 1000	USA
Dispolene 36S	France, Norway, UK
Dispolene 38S	France, UK
Drew dispersant LT	Canada
Enersperse 700	Canada
Enersperse 1037	Norway, UK
Enersperse 2000	Canada
Finasol OSR 52	France, UK
Gamelin 2000	Canada
Gamlen OD 4000 (PE 998)	France, Norway, UK
Inipol IP 80	France, UK
Inipol IP 90	France, UK
Inipol IPC	France, UK
Mare clean 200	USA
Neos As 3000	USA
JD-109	USA
Oilsperse 43	Canada
OSR 5	Norway
Slickgone LT	Canada

Table 3. Overview of the various countries' policies on the use of dispersants.

Country	Approval of dispersants	Deciding agency regarding use
Belgium	YES	Federal department of the environment
Canada	YES	Environment Canada
Denmark	YES	Danish Environmental Protection Agency (EPA)
England	YES	Fisheries Department
Estonia	YES	Estonian Sea Inspection Office
Finland	YES	Finnish Environment Institute (FEI)
France	YES	Department for the prevention of pollution and risks
Germany	YES	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Latvia	YES	Marine Environment Board
Lithuania	YES	Klaipeda Regional Department of Ministry of Environment
Norway	YES	Ministry of Petroleum and Energy
Poland	YES	Director of Maritime Board
Russia	YES	Ministry of Natural Resources
Sweden	YES	Swedish Environmental Protection Agency
USA	YES	United States Environmental Protection Agency

7. Toxicity of dispersants

Knowledge on the toxicity of dispersants comes largely from laboratory studies. Only in a few cases have systematic studies been carried out on the of dispersants at a spill. No common standard method for testing the effectiveness of dispersants has been developed yet, other than certain oil companies' and institutes that have developed their own tests. This has made it difficult to compare different products on the market and has also resulted in wide variances in quality among products on the market. The need remains to develop a testing system that is accepted by all countries and is used for the approval of products based on the requirements of each country.

The physical-chemical processes undergone in the chemical dispersion of an oil are generally well-documented. However, little is known about the dispersed oil's persistence and toxicity in the marine environment. Research from private industry and the producers of dispersants have largely focused on the product's effectiveness in reaching maximum chemical dispersion. It is difficult today to use tests to measure the effectiveness of dispersants. The problem lies in differentiating dispersion due to chemical or natural causes (DeCola, 1999). Many external factors affect the effectiveness of chemical dispersion, such as wind, sea conditions, temperature and salinity, the application of the dispersant and oil type (its physical parameters).

Available research results give no clear-cut answer as to whether chemically dispersed oils have a higher or lower toxicity than naturally dispersed oils. With chemical dispersion, the toxic, aromatic and light components which would otherwise evaporate are likely left in the water mass where they give rise to a higher grade of toxicity than untreated oil (DeCola, 1999). Knowledge of how the weathering process affects the toxicity of dispersed oil over time is still lacking. Future research should focus on acute and even chronic effects of dispersed oil with exposure to the sun, bioaccumulation and other processes that can increase toxicity. Very little is known about the long-term consequences of dispersed oil on the biota and fauna. Such information is very important for forming policy on the use of dispersants.

7.1 Test results of approved dispersants

Test results of approved first generation dispersants showed them to be highly poisonous on test organisms. Toxicity values around 1 mg/L (measured as 48 h LC_{50}, the concentration that kills 50% of test organisms within 48 hours of exposure) were registered for many adult marine invertebrates. Examples of products that showed such values include BP 1002, Slickgone, Gamlen, Essolvene and Finasol SC. The most harmful component in dispersants is the solvent, with very high aromatic concentrations. Second generation dispersants showed lower toxicity values, often between 1 000 – 10 000 mg/L (48 h LC_{50}) in adult organisms. Examples of such products include BP 1100X, some Corexits and Finasol OSR-2. (Lehtinen, 1981).

The United States Environmental Protection Agency (EPA) has conducted toxicity tests on several of the dispersants they allow. Tables 4 through 7 summarise the toxicity of four different dispersants - Corexit 9500, Corexit 9527, Dispersit 1000 and JD-109. The tests studied the toxicity of dispersants alone, dispersants with oil, and oil alone. The toxicity tests were carried out on the minnow *Menidia beryllina* (96-hours test) and the crustacean *Mysidopsis bahia* (48-hours). (EPA, 2001).

In summary, the studies suggest that a mixture of oil and dispersant give rise to a more toxic effect on aquatic organisms than oil and dispersants do alone. Analyses of dispersants alone showed that Corexit 9500 and 9527 are the least harmful for aquatic organisms. Dispersit 1000 and JD-109 showed similar toxicity levels as the oil products.

Table 4. LC_{50} values for Corexit 9500, No 2 Fuel Oil and dispersant + oil for the minnow *Menidia beryllina* (96-hour test) and the crustacean *Mysidopsis bahia* (48-hour test). (EPA, 2001).

Test substances	Species	LC_{50} (ppm)	
Corexit 9500	*Menidia beryllina*	25.20	96-h
	Mysidopsis bahia	32.23	48-h
No. 2 Fuel Oil	*Menidia beryllina*	10.72	96-h
	Mysidopsis bahia	16.12	48-h
COREXIT 9500 & No 2 Fuel Oil (1:10)	*Menidia beryllina*	2.61	96-h
	Mysidopsis bahia	3.4	48-h

Table 5. LC50 values for Corexit 9527, No 2 Fuel Oil and dispersants + oil for the minnow *Menidia beryllina* (96-hour test) and the crustacean *Mysidopsis bahia* (48-hour test). (EPA, 2001).

Test substances	Species	LC_{50} (ppm)	
Corexit 9527	*Menidia beryllina*	14.57	96-h
	Mysidopsis bahia	24.14	48-h
No. 2 Fuel Oil	*Menidia beryllina*	10.72	96-h
	Mysidopsis bahia	16.12	48-h
COREXIT 9527 & No 2 Fuel Oil (1:10)	*Menidia beryllina*	4.49	96-h
	Mysidopsis bahia	6.60	48-h

Table 6. LC50 values for Dispersit 1000, No 2 Fuel Oil and dispersants + oil for the minnow *Menidia beryllina* (96-hour test) and the crustacean *Mysidopsis bahia* (48-hour test). (EPA, 2001).

Test substances	Species	LC_{50} (ppm)	
Dispersit 1000	*Menidia beryllina*	3.5	96-h
	Mysidopsis bahia	16.6	48-h
No. 2 Fuel Oil	*Menidia beryllina*	11.6	96-h
	Mysidopsis bahia	11.7	48-h
DISPERSIT 1000 & No 2 Fuel Oil (1:10)	*Menidia beryllina*	7.9	96-h
	Mysidopsis bahia	8.2	48-h

Table 7. LC50 values for JD-109, No 2 Fuel Oil and dispersants + oil for the minnow *Menidia beryllina* (96-hour test) and the crustacean *Mysidopsis bahia* (48-hour test). (EPA, 2001).

Test substances	Species	LC_{50} (ppm)	
JD-109	*Menidia beryllina*	1.9	96-h
	Mysidopsis bahia	1.18	48-h
No. 2 Fuel Oil	*Menidia beryllina*	9.35	96-h
	Mysidopsis bahia	3.13	48-h
JD-109 & No 2 Fuel Oil (1:10)	*Menidia beryllina*	3.84	96-h
	Mysidopsis bahia	3.51	48-h

The EPA has also carried out tests to measure the effectiveness of dispersants on oil (Swirling Flask Dispersant Effectiveness Test) and compared their results with the manufacturer's. The research was carried out on two different crude oils - Prudhoe Bay Crude Oil and South Louisiana Crude Oil (EPA, 2001). The comparison showed that tests carried out by the manufacturer generally show a higher effectiveness of the dispersant than the EPA's test (Table 8). The variation in results suggests that judgement of dispersants' effectiveness is not always so representative.

Table 8. Comparison of the effectiveness (%) of four dispersants on two different crude oils (Prudhoe Bay Crude Oil and South Louisiana Crude Oil) as found by the EPA and the manufacturer (EPA, 2001).

Oil	Corexit 9500		Corexit 9527		Disperit 1000		JD-109	
	Dispersant's effectiveness (%)							
	Manuf-acturer	EPA	Manuf-acturer	EPA	Manuf-acturer	EPA	Manuf-acturer	EPA
Prudhoe Bay Crude Oil	45,3	49,4	37,4	51	40	52	29	30,02
South Louisiana Crude Oil	54,7	45,4	63,4	31	105	47,9	91	52,84
Mean value	50,0	47,4	50,4	41	73	51	58,5	41,43

8. Analysis of the pros and cons to using dispersants at oil spills

An account of the pros and cons for the use of dispersants to combat oil spills in the sea is presented in Table 9. From an environmental point of view, the best method to control oil is naturally to remove the oil from the water using mechanical methods. When these methods do not work or there are other reasons for not using them, chemical dispersion of oil can be an alternative. If the decision is made to use dispersants instead of mechanical combat methods, one should keep in mind that chemically dispersed oil reduces the chances for later mechanical clean-up. Dispersants can only be used within a limited time period. The window for using dispersants at an oil spill is short. Chemical treatments are most effective during the first few hours after the oil spill (Liukkonen, 1997, IMO, 1995). In addition, applying dispersants is only possible during daylight hours when one can still see the extent of the oil.

In certain situations, using dispersants to combat oil spills in seas can be preferred as mechanical control actions are not always successful. Chemical dispersion prevents the oil from emulsifying. The advantage of chemical control is that it decreases the damage oil can cause on birds and marine mammals. In addition, the number of incidents where the oil slick affects beaches will also be reduced or prevented. In the case of an oil slick moving towards the coast, strategic use of dispersants can disperse the oil vertically towards deeper waters instead of it moving along the water surface towards shallower and more productive areas by the coast.

The research on toxicity of oils mixed with dispersants (section 5.1) has, however, shown high toxicity values even when the dispersant per se was not very toxic. Furthermore, a dispersant is not always effective on all types of oil. An effective dispersion and formation of an oil cloud underwater can produce harmful effects for aquatic organisms in the ecosystem, which were not previously affected by the oil spill. If the oil is not sufficiently dispersed, there is even a risk that drops coagulate again and build a new film of oil. It is therefore important for the amount of mixing energy to be high for effective dispersion.

Table 9. Pros and cons for the use of dispersants at oil spills.

PROS	CONS
• The oil does not remain on the water surface • Often the method that produces the fastest results • Compared to other methods, dispersants are more effective in weather conditions that create fast mixing of water • Easy to apply • Prevents the oil from emulsifying • Grinds up the oil making natural decomposition easier • Seabirds and marine mammals can be saved • Prevents oil contamination of beaches	• Builds an oil cloud underwater and can product harmful effects for aquatic organisms that would otherwise not have been affected by the oil • Not always effective on all oil types • Limited window of time for use (relatively short) • Application is only possible when the oil slick is visible • Must be used where water masses are large for effective dilution • Mixing of oil and dispersants can be more toxic than each part individually • Few studies looking at long-term effects in the field • If the oil is not sufficiently dispersed, drops can coagulate again • Oil drops can settle • During beach clean-up, dispersants can increase the penetration of oil into the sedimentation • Few field studies on the effects of bioaccumulation

9. Risk assessment – the use of dispersants in Swedish waters

From an environmental point of view, using dispersants at an oil spill can be both good and bad for the marine environment. Sweden is surrounded by two marine environments with different characteristics - the West coast with pronounced marine characteristics and the Baltic Sea with special brackish water characteristics. Based on the different characteristics of these two environments, the judgement on the use of dispersants varies.

In a risk analysis of the use of dispersants at an oil spill in Swedish waters, socio-economic values as well as biological values must be taken into account. Ecologically sensitive environments include amongst others, beach meadows, bays that are important breeding areas, and beaches. In a risk assessment, the acute toxic effects brought about by the oil in a sensitive area are compared to the dispersant's toxic effects at the actual treatment area.

Given their low salinity and limited volume of water, dispersants should never be used as a combat method in freshwater environments.

9.1 The Kattegat and Skagerrak

The relatively high salinity of the Kattegat and Skagerrak makes it possible for dispersants to be used as a method to combat oil spills (see Figure 2). One limiting factor, though, is the short window of time when dispersants are most effective – namely, the first few hours after the oil spill. An oil spill far out at sea may not be noticed for a few days or even a week, when the oil starts to near the coast and has already undergone changing processes. By this point in time, dispersants are no longer effective. If, however, the oil spill is noticed shortly after the accident, dispersants may be effective, particularly during the summer months. The effectiveness of dispersants are limited again during the winter because of the low water temperatures (see Figure 3).

The Kattegat and Skagerraks' amount of mixing energy is kept low by a strong halocline which limits vertical mixing. The amount of mixing energy is important for complete dilution, which is not achieved in the Kattegat and Skagerrak.

In coastal areas, the argument against using dispersants is strong. During the summer months, many fish species spend the first phases of their lives in shallow areas. Mussel and fish-farms are likely to incur greater damage if oil is dispersed nearby than if an oil slick floats by on the surface.

Based on the factors affecting the use of dispersants in the Kattegat and Skagerrak (presented in Table 10), it is found that chemical methods are not advisable.

Table 10. Pros and cons to the use of dispersants in the Kattegat and Skagerrak.

PROS	CONS
• Relatively high salinity	• Low amount of mixing energy • Long time before oil spills at sea may be noticed • Low water temperatures limit chemical methods to the summer months • Many reproductive areas can be damaged

9.2 The Baltic Sea

The Baltic Sea has a number of peculiarities that require special consideration in the risk assessment of dispersants. Purely hydrographically, the Baltic Sea is not an ideal environment for the chemical dispersion of oil. The main reasons for this is low water depth, extremely slow turnover rate and low salinity, all of which reduce the effectiveness of dispersants. In addition, a large portion of the Baltic Sea's surface is frozen over or mixed with ice throughout the winter months. Low water temperatures combined with a low salinity (Figure 2) give little chance for dispersion to succeed. The most important factors against using dispersants in the Baltic Sea are the environmental factors – the risk for long-term damage given the low amount of mixing energy, low temperature and poor oxygen content. Increased use of dispersants would result in increased oil content in the water. The oil would then eventually reach the soft seabed that covers the majority of the Baltic Sea's seabed. The long-term environmental consequences are uncertain, but productivity on the seabed will certainly decrease (Lehtinen, 1981). One study of the long-term effects on bottom-dwelling organisms was conducted at the oil spill ”Tsesis” in 1977 and showed that several years after the spill, following the sedimentation of the oil, the number of bottom-dwellers fell (Elmgren et al, 1983).

In certain extreme cases with high stakes, such as ecologically valuable breeding sites for seabirds or a tight gathering of seabirds (e.g., the auk colonies by Gotland), a limited use of dispersants can be advantageous environmentally.

Based on the factors affecting the use of dispersants in the Baltic Sea (presented in Table 11), it is found that chemical methods are not advisable.

Table 11. Pros and cons to the use of dispersants in the Baltic Sea.

PROS	CONS
• Save, for example, ecologically valuable breeding areas	• Low salinity • Low amount of mixing energy • Long time before oil spills at sea ma be noticed • Low water temperatures with parts of the Baltic Sea being frozen over or mixed with ice during the winter months • Many reproductive areas can be damaged

10. Recommendations for the use of dispersants at sea

Based on the knowledge IVL has on dispersants and their effects, IVL can not recommend their use in Swedish waters. This is based on the deciding factors for effective dispersion – water temperature, salinity, and amount of mixing energy – none of which are optimal in either the Kattegat and Skagerrak or the Baltic Sea. Before dispersants can be recommended at all, more studies need to be conducted looking at the spread and bioaccumulation of dispersants at sea and what effects they can give rise to.

11. Suggestions for future research and analyses

Over the course of this research, gaps in current knowledge were identified. The main areas that need future research are the spread of dispersants and how dispersion products and dispersed oil bioaccumulate. The long-term effects of dispersants need to be studied. In order to adequately understand the effects of oil dispersants on aquatic systems, the following studies should be undertaken:

- Long-term effects of dispersed oils on aquatic organisms
- Bioaccumulation of dispersants and dispersed oil
- Does dispersed oil lie on the halocline in the Kattegat and Skagerrak and the Baltic Sea? Is there a risk that dispersed oil may coagulate again?
- Analysis of the environmental effects of dispersants used on past oil spills
- Analysis of the use of sinkers, beach cleaning agents, etc.

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